Influence of Soybean Planting Date and Maturity Group on Stink Bug (Heteroptera: Pentatomidae) Populations

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ABSTRACT Field experiments were conducted in Stoneville, MS, to determine the impact of soybean planting date and maturity group on stink bug (Heteroptera: Pentatomidae) populations. Maturity group IV and V soybeans were planted on three planting dates in 2003 and 2004. Planting dates were late March– early April, late April– early May, and late May– early June. Plots were sampled weekly with a standard 38.1-cm-diameter sweep net. Planting date and maturity group each had a significant effect on stink bug populations. In general, the earliest planting date had the lowest densities of stink bugs, whereas the latest planting date had the highest densities of stink bugs. Over the 2-yr period, cumulative numbers of stink bugs (SE) ranged from 17.9 (6.25) per 25 sweeps for the first planting to 190.9 (20.03) per 25 sweeps for the third planting date when averaged across maturity groups. Additionally, stink bug populations were generally lower on maturity group IV soybeans than on maturity group V soybeans. Cumulative numbers of stink bugs on maturity group IV soybeans averaged 52.4 (26.23) and 25.2 (6.93) in 2003 and 2004, respectively. On maturity group V soybeans, cumulative numbers of stink bugs averaged 96.9 (28.05) and 85.7 (40.84) in 2003 and 2004, respectively. These data provide valuable information about the population dynamics of stink bugs and indicate that early plantings of maturity group IV soybeans in the mid-South will escape heavy stink bug densities.

KEY WORDS *Euschistus servus*, *Acrosternum hilare*, *Nezara viridula*, population dynamics

SOYBEAN PRODUCTION HAS BECOME more important to the agricultural economy of the mid-southern United States in recent years (Williams 1999). Increased yields, decreased production costs, and higher commodity prices have resulted in an overall increase in economic returns from soybeans in the mid-South (Boquet 1998, Heatherly and Spurlock 1999). Traditionally, maturity group V, VI, and VII soybean varieties were grown in the mid-southern states of Louisiana, Mississippi, and Arkansas. These varieties typically were planted in May and early June after planting of cotton. During the last 10 yr, there has been a shift in the soybean maturity groups and planting dates in this region. Currently, the soybeans planted are primarily maturity group IV and early group V varieties. Additionally, the majority of the soybean acres are planted in April as opposed to May.

The early soybean production system was proposed for the mid-South as a method to avoid the high temperatures and extended periods of drought typical of late-July and August in the mid-South (Heatherly 1999). Maturity group V, VI, and VII soybeans planted in May typically begin setting pods in early to mid-August and begin filling pods in late August (Heatherly 1999). This period, which is when the crop is most susceptible to environmental stresses, coincides with periods of high temperatures and extreme drought. In contrast, maturity group IV and V soybeans planted in April begin flowering in May and June and fill seeds in June and July (Heatherly 1999). This results in the critical stages of reproductive development occurring before periods of high temperatures and drought. The benefit of the program has been an overall increase in soybean yields in the mid-South. The impact of the early soybean production system has been well documented in terms of avoiding environmental stresses; however, little work has been done to determine the impact on populations of insect pests.

Stink bugs are a key pest of soybeans throughout the United States. In the southern United States, the three most common species found in soybeans annually include the green stink bug, *Acrosternum hilare* (Say), southern green stink bug, *Nezara viridula* L., and brown stink bug, *Euschistus servus* (Say) (Funderburk et al. 1999). Of these, the southern green stink bug makes up the greatest proportion of the complex during most years. Stink bugs are perhaps the most damaging insect pest of soybeans in the United States because of the direct yield losses associated with pod feeding and secondary losses in seed quality caused by the introduction of pathogens. They develop on nu-

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merous cultivated and noncultivated hosts and migrate into soybean fields during the pod set and seed development stages. In a conventional soybean system, the timings of stink bug migration from plants such as *Cassia* spp., *Crotalaria* spp., and field corn, *Zea mays* L., coincide with soybean pod development. In contrast, soybeans that develop pods earlier in the year may mature before this migration occurs. McPherson et al. (2001) determined that early planted soybeans have higher populations of stink bugs during mid-season than soybeans planted at the usual planting date in Georgia. However, soybeans planted in the conventional system experience higher populations later in the season, and those populations are much higher than the populations that occur on the earlier planted soybeans (McPherson et al. 2001). Those results were consistent with results from other states throughout the southern United States (Baur et al. 2000). Overall, stink bug pressure is greatly reduced when early maturing soybean varieties are planted early compared with a conventional soybean system. In that experiment, they did not compare the impact of planting date and maturity group independently. This study will report on the impact of soybean planting date and maturity group independently as well as the interaction between these two cultural practices on stink bug populations in the mid-South.

Materials and Methods

To determine the impact of soybean planting date and maturity group on stink bug populations, plots of soybeans were planted at Stoneville, MS, during 2003 and 2004. Plots were planted in a split block design (Steel et al. 1997). Soybean planting date was the main plot factor and soybean maturity group was the subplot factor. The randomization of maturity groups remained the same among planting dates within a replication. A different randomization scheme was used in each replication. The experiment was replicated three times in 2003 and four times in 2004. During 2003, the soybean varieties included Pioneer 9492RR (maturity group IV) and Pioneer 95B42 (maturity group V) planted on 15 April, 13 May, and 5 June. During 2004, the soybean varieties included Asgrow 4403 (maturity group IV) and Asgrow 5501 (maturity group V) planted on 25 March, 28 April, and 24 May. Plot size was 16 rows (1-m centers) by 27.4 m. All general agronomic practices were followed throughout the season. Plots were irrigated in furrow as needed.

Plots were sampled once per week throughout the growing season by taking 25 sweeps with a standard 38.1-cm-diameter net. Sampling was initiated across the entire test area when the earliest soybeans reached the R1 growth stage. Samples were taken from three rows in each plot, and the total numbers of stink bug adults and nymphs were counted. The mean of these three samples was recorded for statistical analyses. Samples were taken only from the center 12 rows of each plot. The rows sampled were alternated each week so that no row was sampled more than one time every 3 wk. Plots were sampled until no stink bugs were captured for 2 consecutive wk after the soybeans reached physiological maturity (R8), at which time the soybeans were harvested or mowed and removed from the test area.

For statistical analyses, green and southern green stink bug species and life stages were pooled. In addition to green and southern green stink bugs, a separate analysis was conducted for brown stink bugs. This analysis was conducted because brown stink bugs are more difficult to control with insecticides than green or southern green stink bugs (Willrich et al. 2003, Snodgrass et al. 2005). Other stink bug species observed in the plots included *Thyanta* spp. and *Podisus maculiventris* (Say). These species were not included in the analyses. The cumulative numbers of stink bugs were calculated at the end of the season and log-transformed. Analysis of variance (ANOVA) was conducted on the log of cumulative total numbers of stink bugs at the end of the season (PROC MIXED; Version 8.02, SAS Institute, Cary, NC). After analysis, means and ratios were back-transformed and least significant ratios were calculated to determine differences among the soybean planting dates and maturity groups. Differences on a log scale become ratios when converted to the original values.

Results

Stink bug populations varied among different soybean planting dates and maturity groups. There was a significant effect of soybean planting date ($F = 59.68$; df = 2,6; $P < 0.01$) and maturity group ($F = 12.61$; df = 1,6; $P = 0.01$) on cumulative densities of green and southern green stink bugs in 2003 (Table 1). In addition, the planting date by maturity group interaction was significant ($F = 5.20$; df = 2,6; $P = 0.05$). Populations of green and southern green stink bugs were generally lower on early planted and early maturing soybeans than on later planted and later maturing soybeans. Within the maturity group IV soybeans, cumulative numbers of green and southern green stink bugs were significantly different among all planting dates.

Within the maturity group V soybeans during 2003, cumulative numbers of green and southern green stink bugs were significantly different for planting dates 1 and 2 and planting dates 1 and 3. Cumulative numbers of green and southern green stink bug species were not different for planting dates 2 and 3. When averaged across maturity groups, cumulative numbers of green and southern green stink bugs were significantly different among all planting dates.

The cumulative numbers of green and southern green stink bugs were significantly lower on maturity group IV soybeans than on maturity group V soybeans for the earliest planting date and the mean across planting dates in 2003 (Table 1). Cumulative numbers of green and southern green stink bugs were not significantly different among maturity groups for the second and third planting dates in 2003.

Table 1. Impact of soybean planting date and maturity group on cumulative numbers of green and southern green stink bug adults and nymphs per 25 sweeps during 2003

Planting date	Cumulative stink bugs per 25 sweeps (SEM[a])			Ratio V:IV	LSR[b]
	Maturity group IV	Maturity group V	Mean		
1 (15 April)	8.3 ± 1.91	36.1 ± 6.90	17.9 ± 6.25	4.04	2.09
2 (13 May)	89.6 ± 6.42	123.0 ± 34.01	105.5 ± 18.66	1.39	2.09
3 (5 June)	179.7 ± 30.36	202.9 ± 30.48	190.9 ± 20.03	1.13	2.09
Mean	52.4 ± 26.23	96.9 ± 28.05	—	1.85	1.53
Ratio 3:1	20.13	5.62	10.64	—	—
Ratio 3:2	2.01	1.63	1.81	—	—
Ratio 2:1	10.03	3.45	5.89	—	—
LSR[b]	1.96	1.96	1.74	—	—

[a] SEMs are presented to provide information about variability in the original data. Because data were log-transformed to make comparisons, SEs on the original scale can be misleading.

[b] LSR, least significant ratio. Differences on a log scale became ratios when converted to the original values. LSR calculated for $P = 0.05$.

There was a significant effect of soybean planting date ($F = 82.99$; df = 2,9; $P < 0.01$) and maturity group ($F = 154.91$; df = 1,9; $P < 0.01$) on cumulative numbers of green and southern green stink bugs in 2004 (Table 2). The planting date by maturity group interaction was significant as well ($F = 8.24$; df = 2,9; $P = 0.01$). There were significant differences between planting dates 1 and 3 and between planting dates 2 and 3 within the maturity group IV soybeans during 2004. Within the maturity group V soybeans, there were significant differences among all planting dates in 2004.

During 2004, cumulative numbers of green and southern green stink bugs were significantly lower in maturity group IV soybeans than maturity group V soybeans for all planting dates (Table 2). In addition, cumulative numbers of green and southern green stink bugs were significantly lower in maturity group IV soybeans than maturity group V soybeans for the mean of all planting dates.

For brown stink bugs, there was a significant effect of maturity group ($F = 8.13$; df = 1,6; $P = 0.03$) on cumulative numbers per 25 sweeps in 2003 (Table 3). Planting date ($F = 3.57$; df = 2,6; $P = 0.10$) and the planting date by maturity group interaction ($F = 3.77$; df = 2,6; $P = 0.09$) did not have a significant impact on cumulative numbers of brown stink bugs. A significant impact of maturity group was only observed for the first planting date. Maturity group IV soybeans had fewer brown stink bugs than maturity group V soybeans for the first planting date.

During 2004, there was a significant effect of maturity group ($F = 112.51$; df = 1,18; $P < 0.01$) and planting date ($F = 21.58$; df = 2,18; $P < 0.01$) on cumulative numbers of brown stink bugs (Table 4). On maturity group IV and V soybeans as well as the mean across maturity groups, numbers of brown stink bugs were higher for the third planting date than for the first and second planting dates. Additionally, cumulative numbers of brown stink bugs were significantly higher in maturity group V soybeans than maturity group IV soybeans for each planting date and the mean across planting dates.

When averaged across all planting dates and maturity groups, seasonal stink bug populations peaked around the first to second week of September in 2003 and 2004 (Fig. 1). Before that time, the first two planting dates of maturity group IV soybeans and the first planting date of maturity group V soybeans had reached physiological maturity (R8; Table 5) and were removed from the test area. During 2003, stink bug populations peaked on 12 September at a mean (SE) density of 34.3 (8.75) stink bugs per 25 sweeps across the test area. On that date, maturity group V

Table 2. Impact of soybean planting date and maturity group on cumulative numbers of green and southern green stink bug adults and nymphs per 25 sweeps during 2004

Planting date	Cumulative stink bugs per 25 sweeps (SEM[a])			Ratio V:IV	LSR[b]
	Maturity group IV	Maturity group V	Mean		
1 (25 Mar.)	16.3 ± 1.77	34.2 ± 4.41	23.6 ± 4.11	2.10	1.43
2 (28 April)	17.1 ± 2.63	57.5 ± 9.22	31.3 ± 9.06	3.37	1.43
3 (24 May)	57.4 ± 10.34	320.7 ± 31.17	135.7 ± 52.34	5.58	1.43
Mean	25.2 ± 6.93	85.7 ± 40.84	—	3.40	1.25
Ratio 3:1	3.53	9.38	5.75	—	—
Ratio 3:2	3.36	5.58	4.33	—	—
Ratio 2:1	1.05	1.68	1.33	—	—
LSR[b]	1.49	1.49	1.39	—	—

[a] SEMs are presented to provide information about variability in the original data. Because data were log-transformed to make comparisons, SEs on the original scale can be misleading.

[b] LSR, least significant ratio. Differences on a log scale became ratios when converted to the original values. LSR calculated for $P = 0.05$.

Table 3. Impact of soybean planting date and maturity group on cumulative numbers of brown stink bug adults and nymphs per 25 sweeps during 2003

Planting date	Cumulative stink bugs per 25 sweeps (SEM[a])			Ratio IV:V or V:IV[b]	LSR[c]
	Maturity group IV	Maturity group V	Mean		
1 (15 April)	4.4 ± 0.64	10.4 ± 0.64	6.8 ± 1.31	2.36	1.77
2 (13 May)	8.6 ± 1.55	12.2 ± 3.19	10.2 ± 1.81	1.42	1.77
3 (5 June)	10.4 ± 0.28	9.9 ± 1.39	10.1 ± 0.64	1.05	1.77
Mean	7.3 ± 1.02	10.8 ± 1.11	—	1.47	1.39
Ratio 3:1 or 1:3[b]	2.35	1.06	1.49	—	—
Ratio 3:2 or 2:3[b]	1.21	1.24	1.01	—	—
Ratio 2:1	1.95	1.17	1.51	—	—
LSR[c]	1.69	1.69	1.54	—	—

[a] SEMs are presented to provide information about variability in the original data. Because data were log-transformed to make comparisons, SEs on the original scale can be misleading.
[b] Values are reported as the ratio of the higher value to the lower value.
[c] LSR, least significant ratio. Differences on a log scale became ratios when converted to the original values. LSR calculated for $P = 0.05$.

soybeans from the third planting date were at the R6 growth stage (Table 5). Consequently, those soybeans had the highest levels of stink bug populations (Table 1). During 2004, populations peaked on 3 September at a mean density of 19.0 (4.85) stink bugs per 25 sweeps. Maturity group V soybeans from the third planting date were between the R6 and R7 growth stage on that date (Table 5). In general, populations of brown stink bugs were similar between the 2 yr and remained relatively low throughout each year (Tables 3 and 4). In contrast, the fluctuations observed during 2003 and 2004 were primarily the result of increasing populations of southern green stink bugs during September.

Discussion

The early soybean production system has been widely adopted across the mid-southern United States to reduce environmental stresses during times of reproductive development (Heatherly 1999). An added bonus is that these early production systems may also escape injury from some insect pests. In the southern United States, benefits of the early soybean production system have been observed for velvetbean caterpillar, *Anticarsia gemmatalis* Hübner; soybean looper, *Pseudoplusia includens* (Walker); three cornered alfalfa hopper, *Spissistilus festinus* (Say); and stink bugs (Baur et al. 2000, McPherson et al. 2001). Overall, insect pest populations were lower on maturity group IV soybeans planted early than on maturity group V, VI, and VII soybeans planted at normal planting dates. In this study, planting date and maturity group had a significant impact on stink bug populations in Mississippi. In general, early planted soybeans tended to have lower stink bug populations than later planted soybeans regardless of maturity group. Additionally, maturity group IV soybeans tended to have fewer stink bugs than maturity group V soybeans, regardless of planting date. This is particularly true of green and southern green stink bugs. Populations of brown stink bugs remained lower than the other species and varied throughout the season. Similar trends in stink bug populations have been observed in Georgia (Bundy and McPherson 2000, McPherson et al. 2001). Bundy and McPherson (2000) determined that stink bug populations are higher in maturity group VII soybeans than in maturity group V soybeans. As would be expected, stink bug populations also were higher in maturity group VII soybeans than maturity group IV soybeans (McPherson et al. 2001). Similarly, stink bugs did not exceed the economic threshold on ma-

Table 4. Impact of soybean planting date and maturity group on cumulative numbers of brown stink bug adults and nymphs per 25 sweeps during 2004

Planting date	Cumulative stink bugs per 25 sweeps (SEM[a])			Ratio V:IV	LSR[c]
	Maturity group IV	Maturity group V	Mean		
1 (25 Mar.)	3.1 ± 0.73	13.6 ± 1.99	6.5 ± 2.26	4.43	1.62
2 (28 April)	2.4 ± 0.57	9.6 ± 1.41	4.8 ± 1.55	4.05	1.62
3 (24 May)	6.9 ± 0.57	26.1 ± 2.35	13.5 ± 3.84	3.76	1.62
Mean	3.7 ± 0.67	15.1 ± 2.35	—	4.07	1.32
Ratio 3:1	2.25	1.91	2.08	—	—
Ratio 3:2	2.93	2.72	2.82	—	—
Ratio 1:2 or 2:1[b]	1.30	1.42	1.36	—	—
LSR[c]	1.62	1.62	1.41	—	—

[a] SEMs are presented to provide information about variability in the original data. Because data were log-transformed to make comparisons, SEs on the original scale can be misleading.
[b] Values are reported as the ratio of the higher value to the lower value.
[c] LSR, least significant ratios Differences on a log scale became ratios when converted to the original values. LSR calculated for $P = 0.05$.

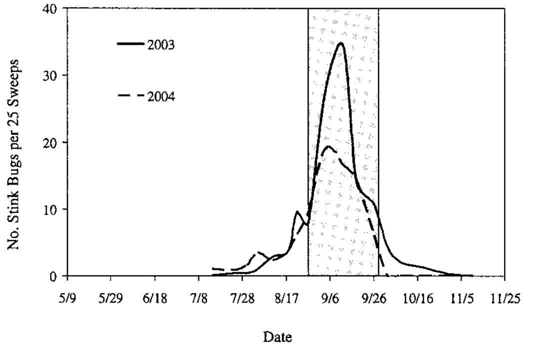

Fig. 1. Seasonal mean stink bug populations in soybeans averaged across planting dates and maturity groups. *N. virdula* L. was the most abundant species, followed by *E. servus* (Say) and *A. hilare* (Say). The shaded area represents the time period when population densities exceeded the recommended threshold of nine stink bugs per 25 sweeps in Mississippi.

turity group IV soybeans in Louisiana, but maturity group V, VI, and VII soybeans required treatment (Willrich et al. 2002). Perhaps an important reason for this is that soybeans in an early production system reach physiological maturity before stink bug populations reach their highest levels in late August and early September.

Generally in the mid-South, spring stink bug populations are primarily found on noncultivated hosts such as vetches, *Vicia* spp., and clovers, *Trifolium* spp. (Todd 1989, McPherson et al. 1994). When these hosts begin to senesce in late spring and early summer, stink bug populations move to other noncultivated hosts (i.e., *Cassia* spp. and *Crotalaria* spp.) in addition to cultivated hosts such as field corn, *Zea mays* L., and soybean (Todd 1989). Movement of stink bugs from one host to another coincides with the phenological stages of those hosts. Stink bugs will feed on most plant structures; however, seeds or fruit are preferred (Panizzi 1997). Consequently, stink bugs migrate from hosts that are near senescence to hosts with seeds or fruit present for feeding and oviposition (Rolston and Kendrick 1961). In this study, stink bug populations on a particular planting date or maturity group peaked when the seeds were fully developed (R5 –R7 growth stage; Fehr et al. 1971) (Table 5). Soybeans that were in the R5–R7 growth stages at the end of August through the first 3 wk of September had stink bug populations that exceeded the current economic threshold in Mississippi (Catchot 2005) of nine stink bugs per 25 sweeps (Fig. 1). Soybeans that reached physiological maturity before stink bug populations peaked experienced less stink bug pressure.

Table 5. Dates of reproductive growth stages for maturity group IV and V soybeans at three planting dates in 2003 and 2004

	Sample dates soybeans were at or beyond the specified growth stage			
	R5	R6	R7	R8
2003				
PD1-Grp4	July 14	Aug. 4	Aug. 18	Aug. 22
PD1-Grp5	Aug. 4	Aug. 18	Aug. 22	Sept. 4
PD2-Grp4	Aug. 11	Aug. 22	Sept. 4	Sept. 12
PD2-Grp5	Aug. 22	Sept. 4	Sept. 12	Oct. 2
PD3-Grp4	Aug. 22	Sept. 4	Sept. 12	Oct. 2
PD3-Grp5	Sept. 4	Sept. 12	Oct. 2	Oct. 8
2004				
PD1-Grp4	June 22	July 15	Aug. 2	Aug. 16
PD1-Grp5	July 15	July 22	Aug. 25	Sept. 10
PD2-Grp4	July 22	Aug. 9	Aug. 16	Aug. 25
PD2-Grp5	Aug. 2	Aug. 16	Sept. 2	Sept. 15
PD3-Grp4	Aug. 9	Aug. 16	Sept. 2	Sept. 15
PD3-Grp5	Aug. 16	Aug. 25	Sept. 15	Oct. 2

PD, planting date; Grp, maturity group.

The early soybean production system has significantly influenced stink bug populations and subsequent injury to soybeans. During the 2003 and 2004 growing seasons, 68 and 78% of the soybean crops, respectively, were planted before 4 May (USDA-NASS 2003, 2004). Consequently, 52 and 73% of the soybeans were senescing (dropping leaves) by the first week of September in those years, respectively. Data from this study showed that stink bug populations peaked at this time, and the soybeans that were senescing probably escaped heavy stink bug infestations. In contrast, 4 and 24% of the soybean crop was planted by the first week of May in 1993 and 1994, respectively (USDA-NASS 1993, 1994). Most of the soybeans in those years were setting pods during the first 2 wk of September and did not start senescing until the end of September. If stink bug populations followed a similar trend during those 2 yr as they did in 2003 and 2004 of this study, the bulk of the soybean crop would have been exposed to heavy stink bug infestations during pod fill. However, soybean phenology may influence stink bug population dynamics and populations during 2003 and 2004 may have peaked in relation to the period when the majority of commercial soybeans in the area were beginning to senesce. For instance, if stink bug populations were at low levels on early planted maturity group IV soybeans and those soybeans represented a large percentage of the overall soybean crop, stink bugs would become concentrated on the later soybeans as the early soybeans began to senesce. Bundy and McPherson (2000) studied the temporal succession of host use by stink bugs in a soybean-cotton agroecosystem. They determined that stink bugs move from early maturing soybeans to later maturing soybeans and cotton. Little work has been done to determine if the early soybean production system that has been adopted in the mid-South has an impact on stink bug populations in other crops.

In this study, stink bug populations were lower in 2004 than in 2003. Using different varieties in 2003 and 2004 may have had an impact on this, but it is not likely. Despite the differences in stink bug population densities between the 2 yr, the relative trends were similar between the 2 yr where more stink bugs were collected from later maturing soybeans than early maturing soybeans.

In conclusion, these data provide important information about the population dynamics of stink bugs.

Both planting date and maturity group had an impact on stink bug populations in soybeans. In general, early planted soybeans had fewer stink bugs than later planted soybeans. Also, maturity group IV soybean had fewer stink bugs than maturity group V soybeans. Future research should focus on studying movement of stink bugs among soybeans at different stages of physiological maturity as well as among other cultivated and wild hosts.

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